



# US LHC ACCELERATOR PROJECT

*brookhaven - fermilab - berkeley*

## US LHC Accelerator Project and Research Program

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## Outline

### US LHC Accelerator (Construction) Project

Project Technical and Schedule Status  
Cost and Schedule Performance

### US LHC Accelerator Research Program

Goals

Planned Research Program Activities  
Program Planning and Funding

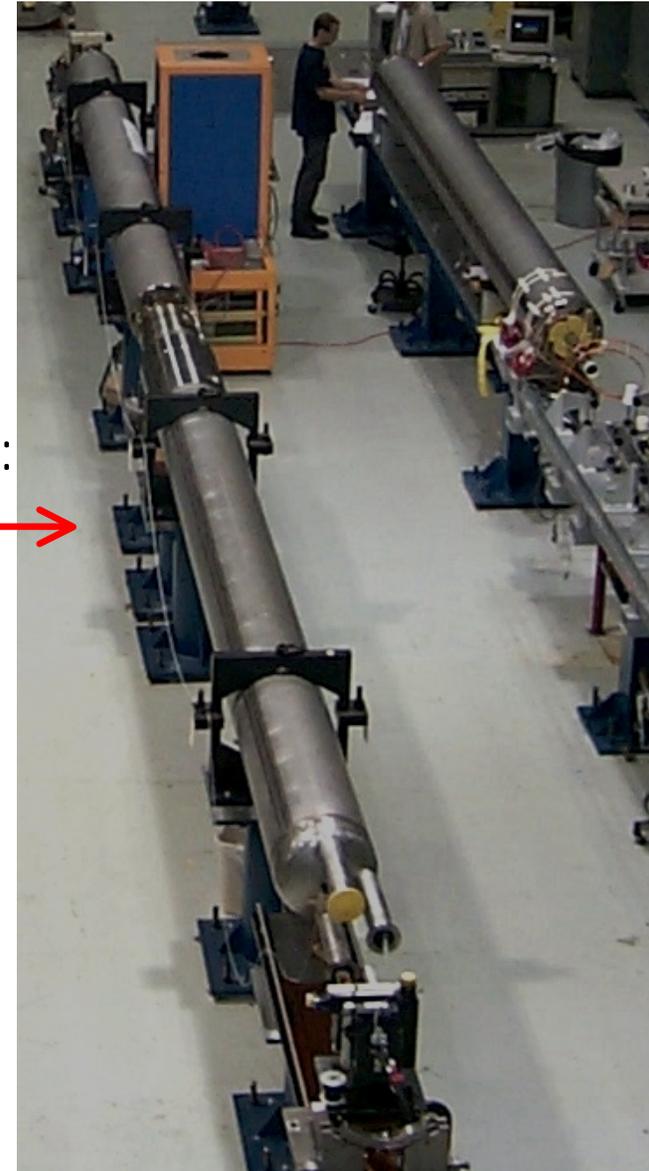
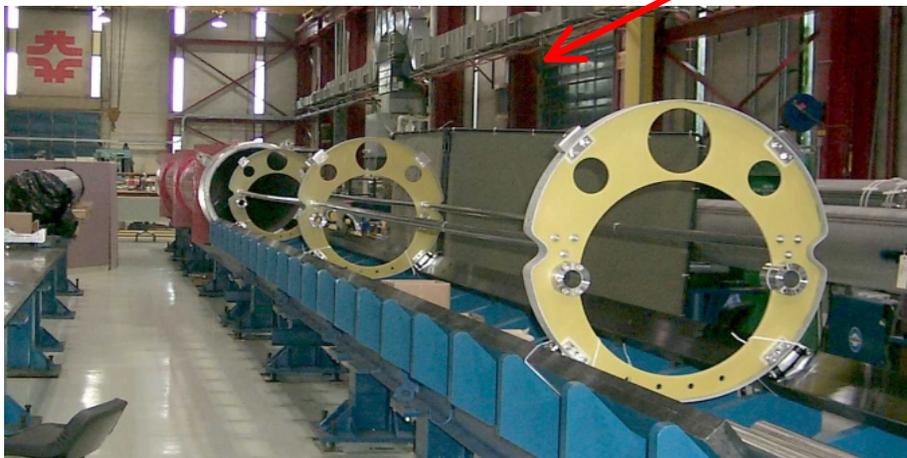


# US LHC Accelerator Project Status

## IR Quadrupoles

IR Quadrupoles are in production.

- MQXB #1-4 complete.
- MQXB #5 coil being prepared for collaring.
- MQXA #1 (KEK) and 1<sup>st</sup> 2 CERN correction coils are at Fermilab.
- First Q2 cold mass assembly almost complete:  
MQXB + CERN corrector + MQXB →  
and insertion into the cryostat is imminent.





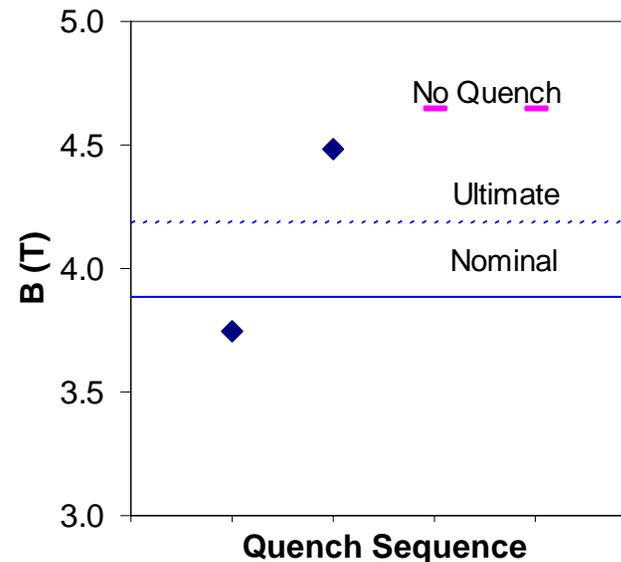
# US LHC Accelerator Project Status

## Beam Separation Dipoles

Beam separation dipoles are in production.

- D1 - Construction of all 5 D1's is complete.
  - Four have been successfully tested and 1 is ready to ship.
- D2 - Six magnets + 2 cold masses complete, last D2 is in process
  - First 2 have been tested.
- D4 - Coil winding is complete.
- D3 - Design complete, except for interface issues with CERN.
  - Coil winding has started.

CERN has changed controlled interface spec. for D2 & D4 -> rework ≈\$50k.  
We are discussing how CERN can offset this cost.



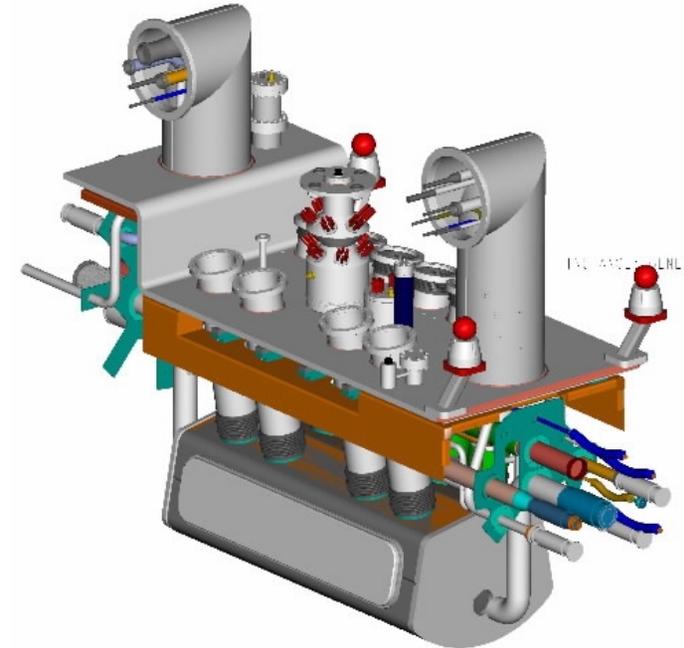


# US LHC Accelerator Project Status

## IR Feed Boxes

### Substantial progress on the IR Feedbox.

- Piorelli has been given the green light for HTS lead production.
- Lambda plate prototype is a success.
- Three qualified vendors have been identified and budgetary quotes received from them.
- Plan to release RFP for fabrication in Sept., sign contract in Dec.
- Schedule is tight relative to CERN installation schedule, but still OK.





# US LHC Accelerator Project Status

## IR Absorbers

IR Absorbers production assembly has started.

- Pre-assembly review in February gave OK for production start.
- Functional and Interface Specifications have been brought up-to-date and resubmitted to CERN.
- Interfaces of TAS with ATLAS and CMS shielding have been changed by CERN, despite having approved Interface Specs.

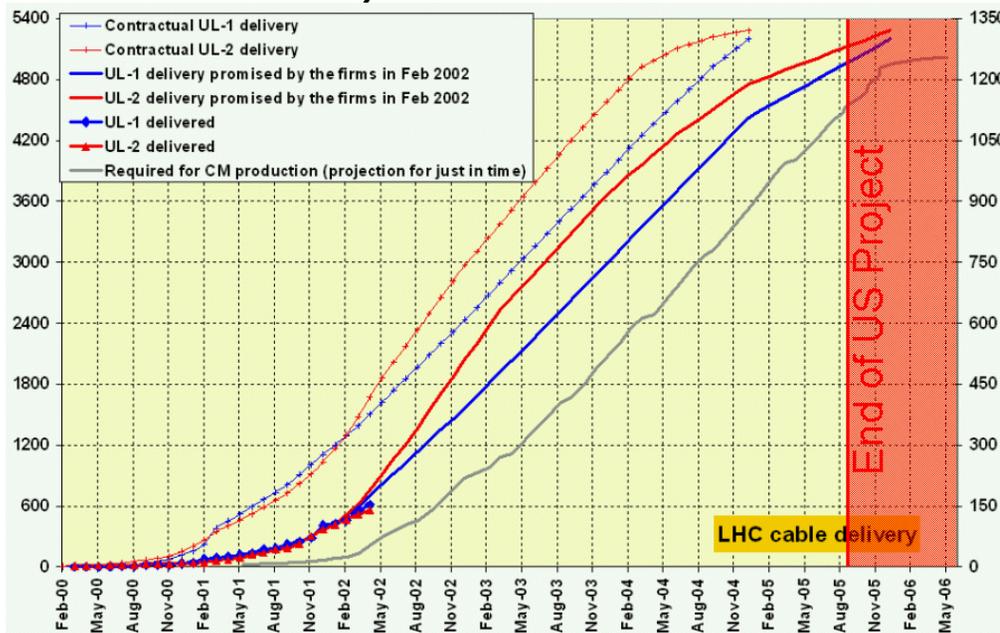




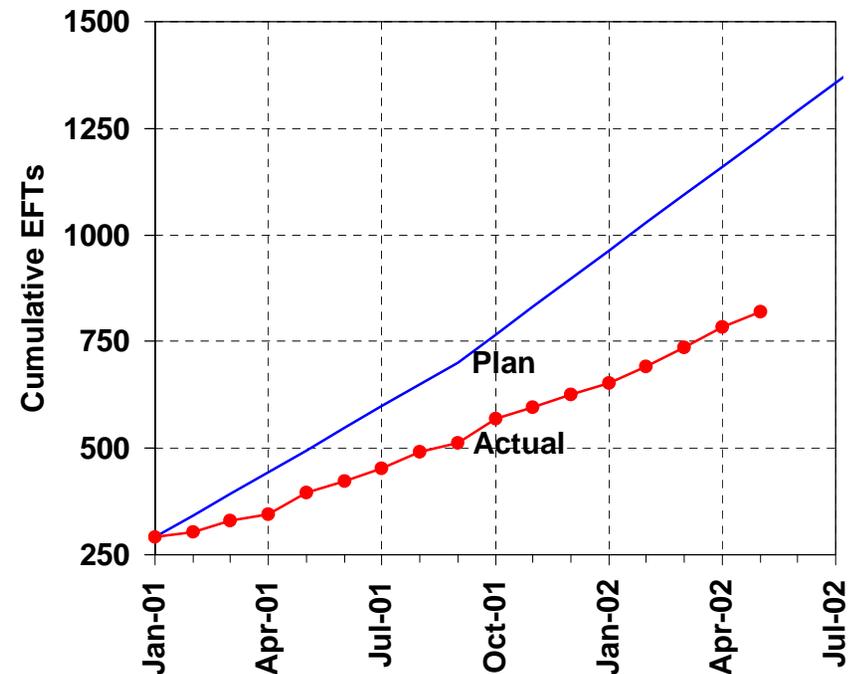
# US LHC Accelerator Project Status Superconductor Testing

## Production SC cable testing continues.

- Rel. to plan made in 2001, sample rate from CERN is about 60% of planned rate (=60% of BNL's capacity); no sign of acceleration.
- Should reach peak rate soon, and continue through at least FY04.
- Recent cost experience is favorable.
- Some samples will be delivered after FY05 and will have to be tested by CERN.



J. Strait - US LHC Accelerator Project





# US LHC Accelerator Project Status Schedule Summary

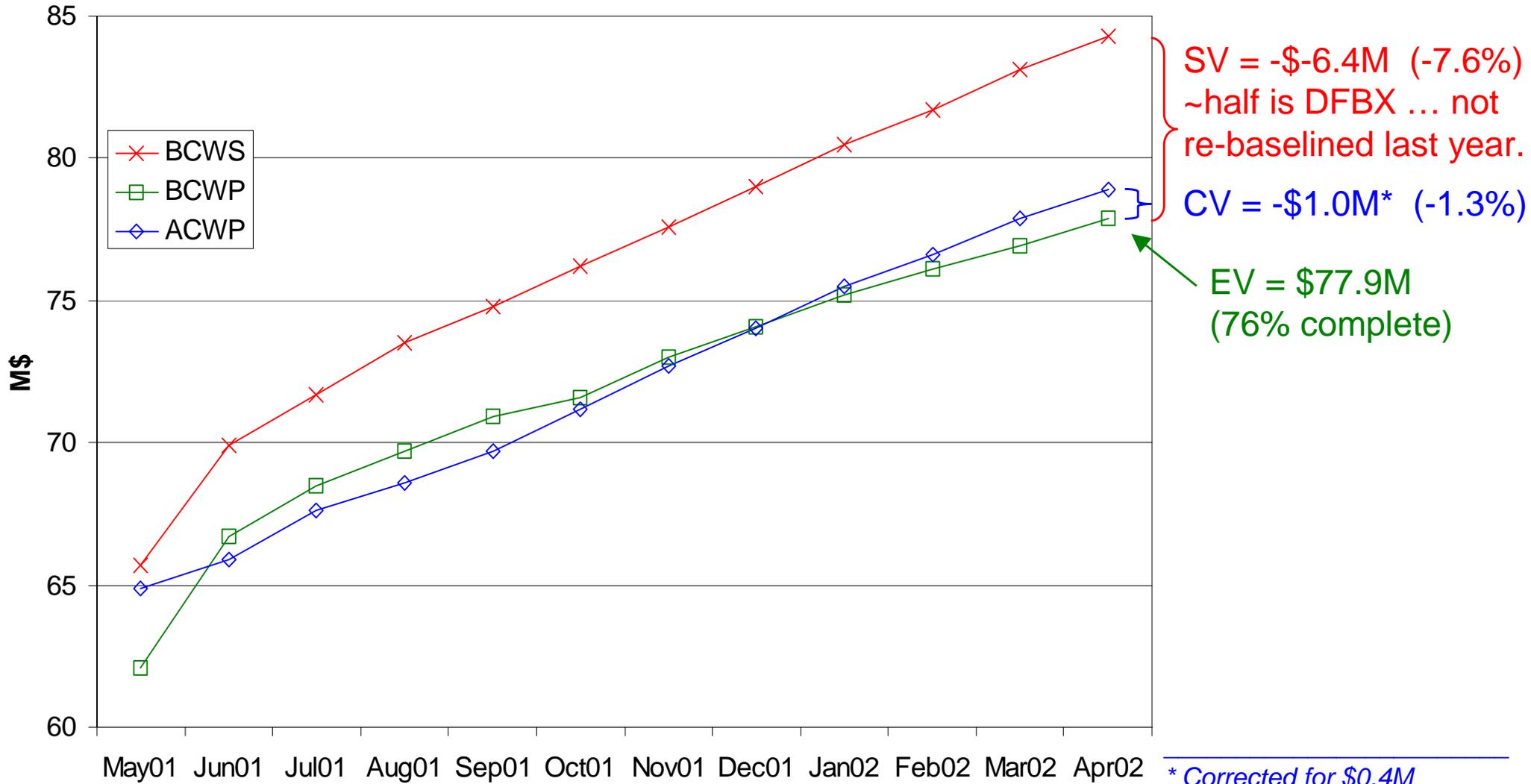
## Schedule situation remains satisfactory:

- Overall the project is ~5 months behind *our* schedule.
  - Somewhat less for quads (2-3 months)
  - Somewhat more for absorbers and cable test (~6 months)
  - Feedbox not re-baselined last year, and is ~1.5 years behind its (old) baseline; first delivery is expected to be *just in time*.
- Minor schedule issues with delivery of CERN-provided components are being addressed.
- New CERN installation schedule delays our required delivery dates by 3-6 months . . . and in most cases another ~6 months of flexibility exists in the CERN schedule for our items.
- We remain ahead of schedule for delivery of our equipment to CERN by the required installation dates.



# Cost and Schedule Performance

Through April 2002



\* Corrected for  $\$0.4\text{M}$  accounting issue at Fermilab.



## Cost and Schedule Performance

Causes of unfavorable cost and schedule trends:

- Start-up problems with quads and dipoles, which appear to have been solved.
- Difficulty completing DFBX design, which is being addressed.
- While these problems are being or have been dealt with, others may still arise.

Cost risk from CERN-imposed changes still exists.

- We are working with CERN to minimize the number of changes and to find ways to offset the costs.



# US LHC Accelerator Project Summary

- Technical progress is excellent.
- There are no major schedule issues.
- Cost and contingency situation requires continued vigilance.
- Excellent and constructive working relations continue with CERN (and KEK).
- We expect to deliver on our commitments to CERN  
Full technical performance,  
On time,  
Within our budget.



## US LHC Accelerator Research Program

The **US Hadron Accelerator Community** and CERN plan to **continue the collaboration** established for the construction of LHC.

The goals of this program are to

- **Extend and improve** the performance of the LHC, so as to **maximize its scientific output**, in support of US-CMS and US-ATLAS.
- Maintain and develop *the US labs' capabilities*, so that the *US can be the leader* in the next generation of hadron colliders.
- Serve as a vehicle for US accelerator specialists *to pursue their research*.
- *Train future generations* of accelerator physicists.
- It is the next step in *international cooperation* on large accelerators.

Fermilab has been appointed the “Host Laboratory” to lead this program.

**CERN management strongly supports our continued collaboration.**



## Planned Activities

Our program is organized in four areas of research:

- **Accelerator physics** experiments and calculations.
  - Understanding performance limitations of current IRs and developing new designs.
  - Participation in the sector test and machine start-up.
  - Beam dynamics calculations and experiments.
- Developing **high performance magnets** for new higher luminosity IRs.
  - Large-aperture, high gradient quadrupoles using Nb<sub>3</sub>Sn.
  - High-field beam separation dipoles and strong correctors.
- Developing **advanced beam diagnostics and instrumentation**.
- **Commissioning our hardware** for the LHC.



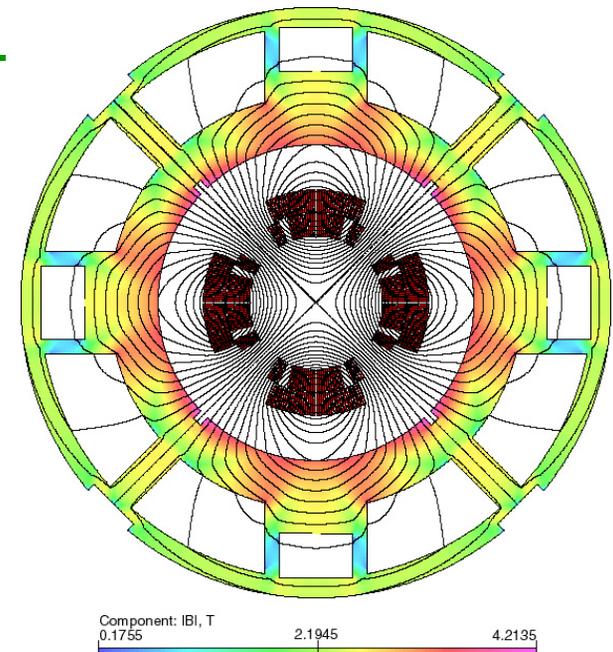
## Interaction Region Development

- The IRs will be among the limiting systems. Replacement of the existing quads is a necessary **route to higher luminosity**.
- The existing quadrupoles have a radiation lifetime of 6-7 years at design luminosity, and **we must be prepared to replace them by about 2014**.
- **US-CERN-KEK collaboration meeting on IR upgrade options** was held 11-12 March 2002.
  - Second meeting is planned for November 2002.
- Several designs for new IRs have been proposed.
  - Maintain the existing optical layout, but with **larger aperture quadrupoles made of Nb<sub>3</sub>Sn superconductor**.
  - Re-arrange the IR to place a beam separation dipole before the quads, which then become **smaller aperture, twin-bore magnets**.



## US Program on IR Upgrade Magnets

- **Goal:** Development of **technologies and prototypes** of superconducting magnets for **high-luminosity inner triplets**, as part of an upgrade program to raise LHC luminosity  $10^{34} \rightarrow 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ .
- **Program focus is on Nb<sub>3</sub>Sn, large-aperture quads.**
  - Builds on and is complementary to “generic” Nb<sub>3</sub>Sn dipole R&D programs.
  - Initial program is to develop technologies, not specific designs.
  - Specific design choices will be made after several years of magnet R&D and related accelerator design studies.
- **Program also considers development of high-field beam-separation dipoles**, required in all IR upgrades scenarios under consideration.
- **Large-aperture linear and non-linear correction magnets** will have substantially higher pole-tip fields than in the baseline IRs and may become quite challenging.

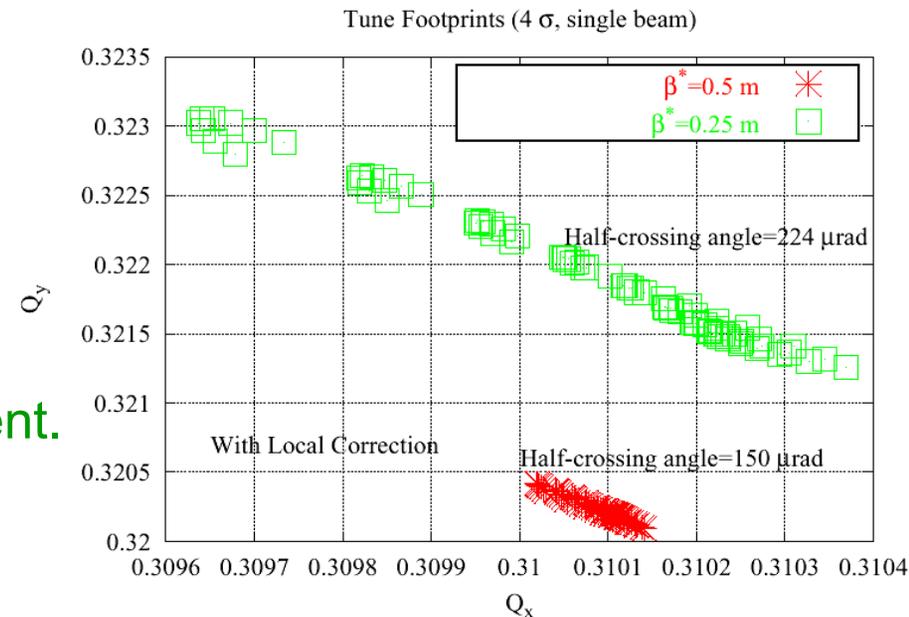




# Accelerator Physics

A broad range of accelerator physics activities are planned.

- Interaction Region studies.
  - 2<sup>nd</sup> generation IR designs.
  - Performance studies for baseline IR.
- AP calculations and experiments.
  - Beam-beam interaction studies.
  - Electron cloud studies.
  - Synchrotron radiation in cryo environment.
  - Studies of feasibility/applicability of new instrumentation methods.
- Machine development.
  - Injection test from IR8 to IR6 - 2006.
  - Machine start-up and commissioning - 2007-2008.
  - Ongoing beam studies and machine development - 2008...
- LHC-relevant machine studies with RHIC and Tevatron.
- Remote data acquisition and (eventually) control room

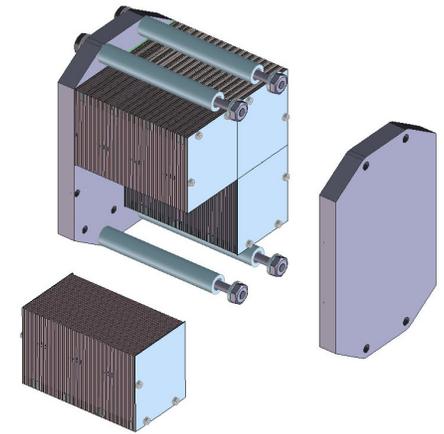




## Instrumentation and Diagnostics

### Development and possible implementation of “2<sup>nd</sup> generation” diagnostics:

- Luminosity instrumentation to be installed in IR absorbers.
  - Fast, bunch-by-bunch measurement.
  - Feedback signal for keeping beams in collision.
  - R&D started under construction project.
- Longitudinal profile monitor.
  - Conceptual design studies have begun.
- Phase-locked loops for tune and chromaticity control.
  - Based on systems currently being developed for RHIC.



### Longer-term ideas, whose feasibility or necessity must be demonstrated.

- Electron lens, currently being developed for the Tevatron.
- Bunch-by-bunch closed orbit control and feedback system.
- Other advanced feedback systems, to be developed as ideas emerge or limitations of LHC become known.



## Hardware Commissioning

- US responsibility for systems delivered under the present construction project ends when CERN accepts them (2002-2004).
- We plan, as part of the research program, to participate in the commissioning of our equipment in the LHC tunnel.
  - Serve as 'consultants' to CERN during installation of our equipment (2004-2006).
  - Full participation in 1<sup>st</sup> operation of our systems - quads, dipoles, feedboxes, absorbers (2005-2007).
    - Cooldown and powering of magnets.
    - Operation of cryogenic control systems.
    - Quench protection.
    - Vacuum and alignment.
    - First beam operation.



## US LHC Accelerator Program Advisory Committee

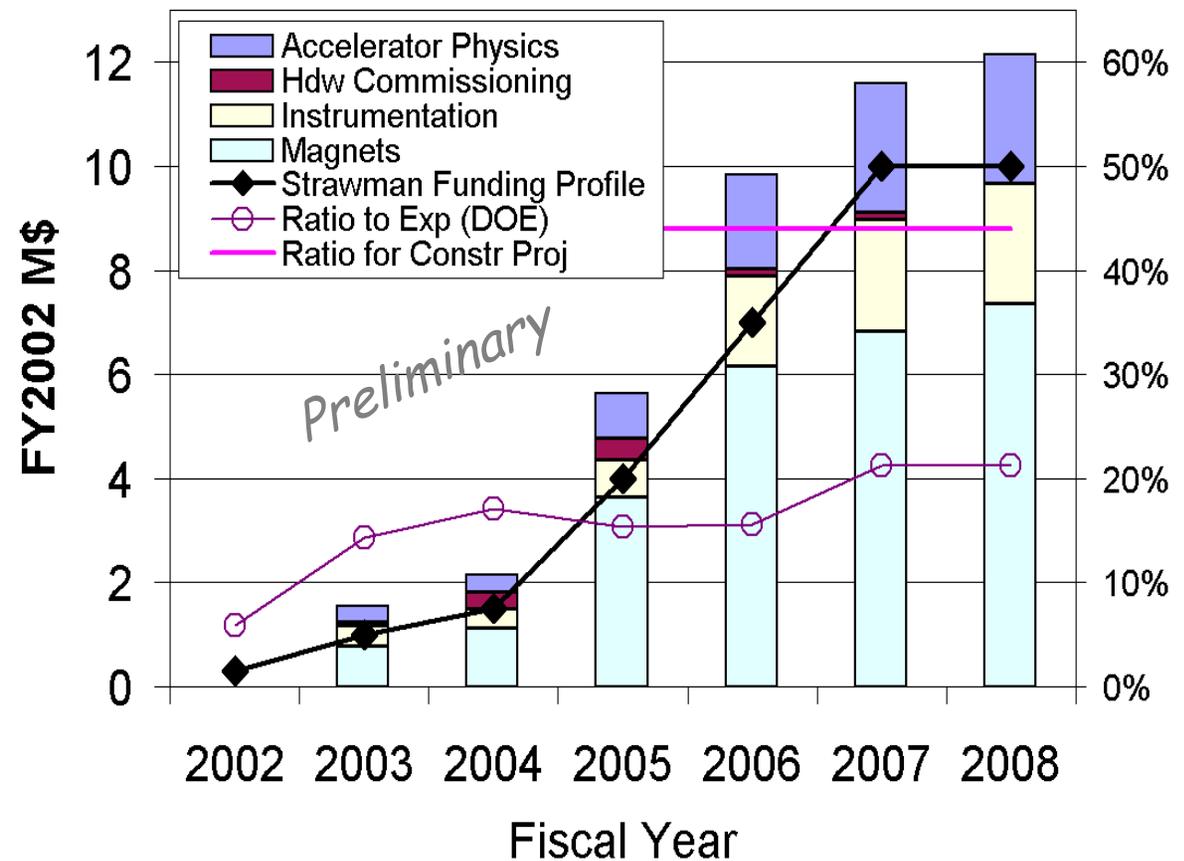
The US LHC Accelerator Program Advisory Committee (LAPAC) has been formed to advise the Program Leader on the scientific program.

- **LAPAC members:** J. Galayda (SLAC – Chair), A. Chao (SLAC), A. Devred (CEA/CERN), H. ten Kate (CERN), C. Rode (JLab), H. Weerts (MSU).
- **First meeting** on 17-18 June 2002.
- **Charge to the LAPAC:**
  - Consider the scientific and technical quality of the proposed program,
  - Offer advice as to the relevance, relative priorities and appropriate schedules for the proposed activities.
  - Evaluated with respect to the degree to which program elements support the objectives of maximizing the scientific output of the LHC, and contributing to the advancement of the domestic US high energy physics and accelerator programs.



## Cost Estimates and Funding

- We are developing cost estimates for all program elements, with a ~5 year time horizon, which we will update yearly.
- The Program is **defined by the science and technology** to meet the Program goals, and will be carried out based on optimal use of resources at the three labs.
- We lack specific guidance on funding, but have made a reasonable estimate, for planning purposes, based on informal discussions with DOE.





# US LHC Accelerator Research Program Summary

- US collaboration on the LHC accelerator is an essential component of the US HEP program.
  - Supports CMS and ATLAS by improving LHC performance.
  - Advances our capabilities in accelerator physics and technology.
- The participants at all 3 labs have agreed on the scientific program
  - Accelerator Physics
  - High performance magnets
  - Advanced beam instrumentation and diagnostics
  - Commissioning of our hardwareand agreed on the management approach.
- Advice from our Program Advisory Committee (LAPAC) will help refine the scientific and technical program.